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IDENTIFYING WAREHOUSE LOCATION USING HIERARCHICAL CLUSTERING

Summary. Identifying the optimal warehouse location involves a series of qualitative and quantitative factors. The purpose of this study was to use hierarchical clustering to identify the optimal location for a warehouse, which would ensure the lowest cost, a high level of quality in supplying customers and connect the selling and purchasing activities of the businesses operating in the Slovenian automotive industry into a system. The study also aims to demonstrate the applicability of the selected method for identifying warehouse locations in more demanding cases because the very process of identifying a location is dependent upon a company's logistic strategy. The advantage of the method used in this study is that it enables the user to use a combination of the data that is the most important for a company in a given period as well as consistent with the company's chosen business strategy.

WYBÓR LOKALIZACJI MAGAZYNU Z WYKORZYSTANIEM METODY GRUPOWANIA HIERARCHICZNEGO

Streszczenie. Wybór optymalnej lokalizacji magazynu jest zależny od różnych czynników jakościowych i ilościowych. Wykorzystując metodę grupowania hierarchicznego, chcieliśmy określić optymalną lokalizację magazynu, która gwarantuje najniższe koszty, wysokiej jakości obsługę klientów i łączy w spójny system sprzedażową i nabywczą działalność przedsiębiorstw w słoweńskim przemyśle motoryzacyjnym. W badaniu chcieliśmy również udowodnić, że wybrana metoda ma zastosowanie przy wyborze bardziej wymagającego miejsca magazynowania, ponieważ sam proces wyboru lokalizacji jest podporządkowany strategii logistycznej danego przedsiębiorstwa. Zaletą wykorzystanej metody jest to, że umożliwia ona zastosowanie kombinacji tych danych, które w danym okresie są dla przedsiębiorstwa najważniejsze oraz zgodne z wybraną strategią.

1. INTRODUCTION

The changing conditions in the automotive industry at a time when the market and the production are moving from West to East at both the global and the European level require special attention from Slovenian companies. Companies strive to be close to their customers and suppliers, as it is only by maintaining a high quality and a streamlined supply chain that they can ensure global presence, flexibility and successful control of logistics costs. The warehousing process is an integral part of the supply chain and it functions as a coordinator between business functions within the scope of materials

management, with the aim of bridging the gap between the time when a product is manufactured and the time when it is supplied to the final user. Warehousing has a major impact on costs, according to several studies [1-5] that mention warehousing costs as the second most important category of logistics costs, right after transport costs. Warehousing also affects the total logistics cost of a company, as reducing warehousing costs can result in an increase in the other categories of logistics costs. Identifying the optimal warehouse location can prevent an increase in the total logistics costs, which could otherwise occur over time. Choosing the right location for a warehouse in an international environment is therefore one of the most important strategic decisions and takes into account a number of interrelated factors.

The study also analysed car manufacturing trends in those countries where the export and import flows of goods to and from Slovenia are most pronounced. The analysis takes into consideration both labour costs and labour productivity in these countries. The development level of the logistics system of each country is measured by taking into account the length of the transport network, the transport infrastructure and the number of companies per each type of transport. Hierarchical clustering using Ward's method and Euclidean distance measure was used to obtain cohesive groups of most similar countries regarding available indicators. Characteristics of groups were described (mean value of characteristic for group member states was given). Groups were evaluated in all characteristics with regard to median or reference value of indicator. Data processing was carried out using IBM SPSS Statistics 22.

The purpose of this study was to devise a method for selecting warehouse locations that would ensure the lowest cost and high-quality service to customers as well as connect the selling and purchasing activities of the businesses operating in the Slovenian automotive industry into a system. With the use of hierarchical clustering, we intend to set new guidelines for the development of warehouse location selection methods, as such methods can also be used for the selection of a warehouse location in a particular enterprise. The proposed method has the advantage of taking into account the data that is consistent with a company's current strategy for selecting a location for a warehouse. This facilitates better and more customized decision making when selecting potential warehouse locations, which is why the proposed method has an advantage over the other mathematical methods since they are limited to predefined parameters.

2. REVIEW OF THE LITERATURE RELATED TO SELECTING A WAREHOUSE LOCATION

Korpelaa & Tuominen [6] point out the many methods that deal with warehouse location selection merely from a cost point of view. In their study they introduce an integrated approach to the site selection process, where both qualitative and quantitative aspects can be taken into account by using an analytic hierarchy process-based decision aid. Lambert et al. [7] point out that warehouse location decisions should take into account both the macro and micro aspects. Macro aspects are related to the question of where to find a suitable warehouse location that would facilitate the rational acquisition of materials for production and at the same time enable a company to maintain efficiency in the market, within a certain geographical area. The authors highlighted a market-based strategy, a production-based strategy and a strategy that falls between both of the above strategies. Micro aspects of decision-making are defined as factors that directly affect the potential location selected within a wider geographical area. Among the factors that should also be taken into account are the characteristics of the facility, warehouse services, accessibility, proximity to transport terminals and availability of local transport services. Schmenner [8] proposed an eight-step approach to a business location search that we can apply to warehouse location selection decisions. It has been used to select a site or location for a facility. The proposed approach requires close cooperation between the employees of the company. The management initially sets up a team of experts tasked with the responsibility of selecting potential warehouse locations on the basis of various criteria. It is the management that then makes the final decision on the choice of location. Ballou [9] presented a model that is used for locating a single plant, terminal, warehouse, or retail/service point. It has been variously known as the exact centre-of-gravity

approach, the grid method, and the centroid method. The approach is simple since the transportation rate and the point volume are the only location factors. The applicability of the model was presented with a calculation of the warehouse location for the company Limited Distributors, Inc.

Vlachopoulou et al. [10] developed a geographic decision support system for the warehouse site selection process, enabling the manager to use quantitative and qualitative criteria in order to classify alternative warehouses or visualize the best one. The use of the presented process is demonstrated with a practical example. Demirel et al. [11] point out that conventional approaches to the warehouse location selection problem do not take into account all the qualitative and quantitative factors affecting the warehouse location selection. Therefore, they constitute a multi-criteria analysis method based on the use of the Choquet Integral, which is tested on a real-life example of a warehouse location selection problem faced by a large Turkish logistics firm. In this instance, a combination of qualitative and quantitative factors affecting warehouse location selection is taken into account: costs, labour characteristics, infrastructure, and markets. Other criteria are also included, such as tax incentives and tax structures, availability of labour force, quality and reliability of modes of transportation, and proximity to customers.

Ozcan et al. [12] presented the already known warehouse location selection methodologies AHP, TOPSIS, ELECTRE and Grey Theory and compared them in terms of the main characteristics of decision theory and thus the advantages and disadvantages of these methodologies are offered. Later, the application of these methodologies to the warehouse selection problem is presented as a case study, which is characterized in the retail sector that maintains a high degree of uncertainty and product variety, followed by a discussion on how to choose the best warehouse location among many alternatives. Tancrez et. al. [13] developed a model that integrates decisions regarding the selection of the location of distribution centres, the allocation flows and the size of individual shipments. The aim of the model is to facilitate the choice of suitable distribution centres that effectively connect the locations of production facilities with the locations of final customers. This model focuses on the optimization of the cost of inventories and transportation costs. Both cost components are conflicting because if goods are supplied from the factory directly to the end customers the cost of inventories and warehousing is lower, but at the same time the cost of transport increases. The opposite scenario takes place when a company uses distribution centres to supply customers, which ensures that its transport capacities are fully utilized, but also results in an increase in the cost of inventories and warehousing. The purpose of the model is to find solutions that would enable an optimal level of supply and the construction of an effective supply chain network. Durmus & Turk [14] investigate the factors affecting the location selection of warehouses at the intra-urban level on a case study of Istanbul by using a logistic regression model. They found that location-specific factors are effective in the location selection of warehouses in the Istanbul metropolitan area, and warehouse location follows a certain economic rationality at the intra-urban level. Askin et al. [15] developed a novel mathematical model to solve a complex facility location problem determining: the location and capacity level of warehouses to open, the distribution route from each production facility to each retail outlet and the quantity of products stocked at each warehouse and retailer. A genetic algorithm and a specific problem heuristic are designed, tested and compared in several realistic scenarios. Huang et al. [16] have developed an integrated model for site selection and space determination for warehouses in a two-stage network in which products are shipped from part suppliers to warehouses, where they are stored for an uncertain length of time and then delivered to assembly plants. The objective is to minimize the total transportation and warehouse operation costs. This includes the fixed costs related to their locations and the variable costs related to their space requirements for given service levels.

3. RESEARCH METHODOLOGY

Temporal data was analysed by linear trend to obtain an assessment of future trends in car production, labour cost and labour productivity. The regression coefficient was calculated where data for at least three data points was available. Seven countries were grouped into cohesive groups according to all available indicators, i.e. car production in 2013, car production trends, number of

production plants in 2013 [17, 18], transportation infrastructure [19] (length of motorways, railways, number of airports, ports), number of transport enterprises by mode of transport [20], labour cost in 2009 [20], trend of labour cost, employee productivity in 2010 [21], trend of labour productivity, and Slovene merchandise trade with a particular country [22] (import, export). Hierarchical clustering using Ward's method and the Euclidian distance measure was used to obtain cohesive groups of most similar countries regarding available indicators. The characteristics of the groups were described (mean value of characteristic for group member states was given). The groups were evaluated in all characteristics with regard to median or reference value of indicator. Data processing was carried out using IBM SPSS Statistics 22.

4. RESULTS AND DISCUSSION

Table 1 shows measured characteristics per country. Car production in 2013 was highest in Germany and Spain and lowest in Poland. Linear trend analysis indicates probable future growth in car production for the Czech Republic, Germany and Poland and a decrease in other countries. Germany and France had the highest number of production plants in 2013. The coverage with motorways, taking the size of the country into account, is highest in Poland and the Czech Republic and lowest in Germany. Railway coverage is highest in Spain and lowest in the Czech Republic. France has the highest number of airports and the UK has the highest number of ports. The highest number of road transport enterprises is in Spain; sea and river and railway enterprises are most prevalent in Germany, while the UK has the highest number of airport enterprises. Warehousing and transport activities are most developed in Italy, Spain and Germany. The cost of employees is highest in Germany and the UK and lowest in the Czech Republic and Poland. All the countries show a positive trend in employee cost. However, the steepest increase is expected in Spain and France. The lowest increase in labour costs is expected in the UK and Poland. Employee productivity is highest in France and Germany. A growth in productivity is expected in the Czech Republic and Poland, where current productivity is lowest. Import and export activities are most intense between Slovenia and Germany.

Table 1

Data description

Measures	**Czech**	**France**	**Germany**	**Italy**	**Poland**	**Spain**	**UK**
Total production of cars and commercial vehicles in 2000	455492	3348361	5526615	1738315	504972	3032874	1813894
Total production of cars and commercial vehicles in 2005	602237	3549008	5757710	1038352	625443	2752500	1803109
Total production of cars and commercial vehicles in 2010	1076385	2227742	5905985	857359	869376	2387900	1393463
Total production of cars and commercial vehicles in 2013	1132931	1740000	5718222	658207	583258	2163338	1597872
Lin. trend for car production (β)	57488	-136871	18628	-78812	13490	-67259	-25876
Number of production plants in 2010	11	38	47	20	16	15	32
Number of production plants in 2013	11	36	46	23	14	15	30
Country size (km^2)	78866	543965	356970	301333	311889	504880	244100
Length of motorways (km)	745	11412	12845	6668	1070	14554	3686
Size of country/length of motorways	105.86	47.67	27.79	45.19	291.49	34.69	66.22
Length of railways (km)	9470	30404	33576	17045	19725	15932	16408
Size of country / length of railways	8.3	17.9	10.6	17.7	15.8	31.7	14.9

Number of airports	5	62	38	37	9	41	44
Number of ports (sea and river)	5	334	74	86	100	182	731
Number of transportation enterprises (road)	32246	34903	35828	78135	84258	119704	30690
Number of transportation enterprises (sea)	1	692	2156	720	229	271	1225
Number of transportation enterprises (railways)	30	32	193	25	104	11	128
Number of transportation enterprises (airport)	47	497	468	247	189	82	859
Number of warehousing and support activities	4689	9936	15732	23071	9693	16429	9579
Average GAE of ft employees (2000)	4616	26712	34400	19991	6226	17432	37676
Average GAE of ft employees (2005)	7405	30521	38700	22657	6270	20333	42866
Average GAE of ft employees (2009)	10596	34132	41100	23406	8399	26316	38047
Lin. trend for labour cost (β)	660.1	821.9	749.2	385.8	231.9	970.4	82.1
EP p.p.e. 2000	60	126	107	127	56	104	111
EP p.p.e. 2006	70	121	109	111	61	103	113
EP p.p.e. 2010	72	120	105	108	67	110	108
Lin. trend for EP p.p.e. (β)	1.24	-0.62	-0.16	-1.96	1.08	0.54	-0.25
EP p.h.w. 2000	52	135	124	116	46	103	111
EP p.h.w 2006	59	132	128	102	49	104	113
EP p.h.w 2010	62	128	124	101	54	106	110
Lin. trend for EP p.h.w (β)	1.0	-0.7	0.1	-1.6	0.8	0.3	-0.1
Slovene export in 2011	518845	1406754	4389463	2474371	648278	238898	494862
Slovene export in 2013	559767	1140201	4394787	2495085	643821	237416	441171
Slovene import in 2011	584198	1056604	4191791	4000209	469486	460366	358452
Slovene import in 2013	540359	939613	4231075	3512781	495698	378613	388356

GAE = gross annual earnings; p.h.w. = per hour worked; EP = labour productivity; p.p.e. = per person employed; Lin = linear; ft = full-time

The result of clustering by all characteristics is four cohesive groups. The Czech Republic and Poland form the first cluster of the group; France and the UK fall into the second group; the third group includes Germany and Italy, and Spain makes up the fourth group. A description of the group characteristics is given in Table 2. Where a group is comprised of two countries, the mean value of each measured characteristic is given. Where the difference in the values of measured characteristics between groups is high, the median value of the characteristic is calculated and considered as a reference value. For the beta coefficients obtained by linear trend, reference value is 0. The highlighted cells in the table are those in which the group's characteristics are in favour of a possible warehouse location with regards to the reference value. The disadvantageous characteristics with regards to the median/reference value are shown in red text. The countries with the highest number of advantageous characteristics are Germany, France and the UK. France and the UK have high car production, a well-developed transport infrastructure, a high number of transport enterprises and high employee productivity. In comparison, Germany's transport infrastructure is slightly less developed. All three countries have a high-cost labour force. However, further growth of car production for Germany is expected, while car production in France and the UK is expected to decrease. Export and import activities are dynamic between Slovenia and Germany and scarce between Slovenia and the

UK or France. Therefore, Germany is the country with the most optimal conditions for warehouse location.

Table 2

Description of cohesive groups (grey = beneficial characteristics with regards to median/reference value; underline-bold = disadvantageous characteristics with regards to median/reference value)

	Czech & Poland	France & UK	Germany	Italy & Spain	Median / reference value
Tot. prod. of cars and c.v. in 2013	**858095**	1668936	5718222	**1410773**	1539854
Lin. trend for car production (β)	35489	**-81373**	18628	**-73036**	0
Num. of production plants in 2013	**13**	33	46	**19**	26
Size of country / length of motorways	199	57	**28**	**40**	48
Size of country / length of motorways	**12**	16	**11**	25	14
Num. of Airports	**7**	53	**38**	39	39
Num. of Ports (sea and river)	**53**	533	**74**	134	104
Num. of transp. enterprises (road)	58252	**32797**	**35828**	98920	47040
Num. of transp. enterprises (sea)	**115**	959	2156	496	727
Num. of transp. enterprises (railways)	**67**	80	193	18	74
Num. of transp. enterprises (airport)	**118**	678	468	165	316
Num. of warehousing and support a.	**7191**	**9758**	15732	19750	12745
Average GAE of ft employees (2009)	9498	**36090**	**41100**	24861	30475
Linear trend for labour cost (β)	**446**	**452**	**749**	678	0
EP p.p.e 2010	**70**	114	**105**	109	107
Lin. trend for EP p.p.e. (β)	**1.2**	**-0.4**	**-0.2**	**-0.7**	0
EP p.h.w.2010	**58**	119	124	**104**	111
Lin. trend for EP p.h.w (β)	0.9	-0.4	0.1	**-1**	0
Slovene export 2013	**601794**	**790686**	4394787	1366251	1078468
Slovene import 2013	**518029**	**663985**	4231075	1945697	1304841

Tot. prod. = Total production; c.v. = commercial vehicles; GAE = gross annual earnings; p.h.w. = per hour worked; EP = employee productivity; p.p.e. = per person employed; Lin = linear; Num = number; ft = full-time; a. = activities; transp. = transport

As car production is expected to grow in the Czech Republic and Poland and considering the fact that the labour force is cheap and a growth in employee productivity is expected, these two countries have a high potential for further development and could be viewed as possibilities for future warehouse location, especially if importing and exporting activities between Slovenia and these two countries pick up.

4.1. Contribution to theory and practical implications for the warehouse location selection process in companies

The hierarchical clustering method is a frequently used statistical tool. In the example shown above, its use sets new trends in theoretical method development for selecting warehouse locations because the process of location selection can be complemented by new data (qualitative and quantitative factors). This allows better decision making when selecting potential warehouse locations,

which is why the proposed method has an advantage over the other mathematical methods since they are limited to predefined parameters. The following data can also be included in the process of selecting the location for a warehouse: rental costs, land costs, taxes imposed by the individual countries and other relevant information that can make it easier for a company to select a suitable location for a warehouse.

The method presented also has its applications in practice, as it can be used by companies to assist themselves in finding suitable warehouse locations. The first step consists in identifying the geographical areas where the company makes the majority of its sales and purchases of goods. The second step is estimating the number of potential customers and suppliers and their annual revenue. The purpose of this step is to determine the selling and purchasing potential of a certain area. The rest of the data remains the same (labour costs and labour productivity by country the length of the transport network and transport infrastructure and the number of companies by type of transport). The method of hierarchical clustering using Ward's method and the Euclidian distance measure was used to obtain cohesive groups of most similar countries/areas regarding these indicators. The groups were then evaluated in all characteristics with regard to median or reference value of indicator in order to determine the potential warehouse location, which takes into account several qualitative and quantitative aspects.

4.2. The weaknesses and risks connected with the implementation of the proposed method

The proposed method of warehouse location selection requires additional testing on real-life cases in companies. The issue that emerged during the study is that the analysis is based on historical data, while it is the future that is more relevant when it comes to the selection of warehouse location. This is why it would be more sensible to analyse a longer period of time, which would result in a more reliable prediction of future trends. Although hierarchical clustering has many advantages, the fact remains that it is difficult to determine the location of a warehouse by taking into account all the positive factors for the selection. In the example shown, Germany is the country with the greatest potential for a warehouse location because of its strong trade relationship with Slovenia, large number of manufacturing plants, well-developed transport network and high level of employee productivity. The downside is the cost of labour, which is the highest in the EU. Therefore, the final decision on the location of the warehouse must also consider this fact.

The method presented is thus merely a proposal for potential strategic warehouse location, which is why in certain instances hierarchical clustering should be combined with other methods for warehouse location selection. It is also difficult to identify the optimal location for a warehouse because every company has its own logistics strategy and the use of each method serves only as s decision-making tool for the company's management.

5. CONCLUSION AND GUIDELINES FOR FUTURE RESEARCH

Companies must be prepared for the changes resulting from car production, gradually moving towards the east of Europe, which is why effective planning of logistics activities is crucial for their survival in the highly demanding automotive industry. Due to the development of transport infrastructure, transport networks and information technology over the years, the role of warehousing within the logistics system has grown more important in terms of providing an adequate level of service at the lowest total cost. In warehouse management, we are faced with important strategic decisions, which are often related to the planning of the size and especially the choice of suitable warehouse locations.

Identifying the most suitable warehouse location is a task that every company is faced with from the first day of operations. Up to a few years ago, it was standard practice not to change the location of the warehouse over the course of long-term operations. Because of the changes occurring in the international trade markets, companies are forced to pay special attention when selecting a warehouse

location and bear in mind that warehouse locations can no longer be considered permanent. Selecting the location for a warehouse requires companies to take into account any changes that may occur in the future when selecting a suitable location for a warehouse, such as shifts in trade flows, changing customer requirements, high operating costs and other unforeseen factors [23].

The study analysed the available data using the hierarchical clustering method for the purpose of identifying potential strategic warehouse locations that could significantly affect the future operations of Slovenian companies in the global automotive industry. The results of the study showed that the changes that are happening in the automotive industry have not yet started to affect the Slovenian automotive industry, at least not in full, as it is still heavily dependent on the German economy. Germany has emerged as the country offering the best conditions for the location of a warehouse, while the Czech Republic and Poland appear to be a good choice for warehouse locations in the future.

The example presented in the study was used to demonstrate the applicability of the method to the process of warehouse location selection in companies. Choosing the optimal location of a warehouse can be achieved through the use of various methods, which can vary in complexity and in the use of various qualitative and quantitative factors. Most of these methods attempt to include as many of these factors as possible but are hindered by the fact that their options for upgrading and including new aspects of warehouse location selection are limited. The choice of a location for a warehouse remains dependent upon a company's strategy, which is predetermined by its management and changes over time. The advantage of the method used in this study is that it enables the user to use a combination of the data (parameters) that is most important for a company in a given period as well as consistent with the company's chosen business strategy. The hierarchical clustering method can also be used for the selection of the optimal location for a distribution center or manufacturing plant.

The study proposes a new concept of warehouse location selection, which requires additional testing in different companies and on real-life cases. Future research might therefore focus on analysing the actual locations of warehouses in actual companies and comparing them to the locations obtained with the use of the hierarchical clustering method.

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